SYSTEM FOR MONITORING, DETERMINING, AND REPORTING DIRECTIONAL SPECTRA OF OCEAN SURFACE WAVES IN NEAR REAL-TIME FROM A MOORED BUOY

STATEMENT OF GOVERNMENT INTEREST

The research that led to the development of the present invention was sponsored by the National Oceanic and Atmospheric Administration's (NOAA's) National Data Buoy Center. NOAA is a part of the U.S. Department of Commerce, a component of the U.S. Federal government. The United States Government has certain rights in the present invention.

FIELD OF THE INVENTION

The present invention relates to wave measurement using moored buoys. In particular, the present invention is directed toward the National Data Buoy Center's (NDBC) directional wave measurement system, which uses a system of sensors, processors, algorithms, and communications on a moored buoy to measure the components of a directional wave spectrum and transmit the spectrum to a shoreside processing center for analysis and dissemination.

BACKGROUND OF THE INVENTION

Off-Shore buoys are used for a number of purposes: for navigation, communication, and also to measure weather and wave conditions. The National Oceanic Atmospheric Administration (NOAA) through the National Data Buoy Center, maintains a number of offshore buoys to measure water temperature and wave height, among other parameters. This data may then be transmitted to shore and processed and presented as part of weather forecasts, either on the NOAA website, or through NOAA weather radio, for use by Mariners and others, in predicting weather and wave conditions.

The U.S. National Data Buoy Center (NDBC) of the National Weather Service (NWS), a part of the U.S. National Oceanic and Atmospheric Administration (NOAA), operates a large number of buoys in areas of interest to the United States. Each hour (in a few cases every 30 minutes) meteorological, oceanographic, and wave data are acquired, transmitted to shore via satellite telecommunications, and distributed to users following real-time, automated data quality control. NDBC made its first non-directional wave measurements from buoys in 1973 and its first directional wave measurements in 1975. The program has expanded so that now all NDBC buoys make wave measurements and most make directional wave measurements.

While many existing weather data buoys adequately measure wave height, oftentimes other wave data, such as direction, may be useful in marine weather forecasts and for other uses. For example if wave direction is opposite tidal direction, oftentimes conditions can exist near shore where wave heights may increase. In addition, wave direction may differ from wind direction, and thus a report of wind direction may not always be indicative of wave direction. When plotting a course, a mariner may wish to avoid certain wave orientations (e.g., broaching waves) and thus wave direction data may be useful to mariners. Scientists and others may find wave direction data useful in studying shore erosion and other environmental impacts of waves. Furthermore, other wave data, such as wave slope and the like may be useful to oceanographers and engineers, as well as mariners. The term wave spectra is used in the art to describe the distribution of wave parameters as a function of frequency (Hertz (Hz)).

Various idealized spectra are used in oceanography and ocean engineering. Perhaps the simplest is that proposed by Pierson and Moskowitz (1964). They assumed that if the wind blew steadily for a long time over a large area, the waves would come into equilibrium with the wind. This is the concept of a fully developed sea. Here, a long time is roughly ten-thousand wave periods, and a "large area" is roughly five-thousand wave-lengths on a side. Hasselmann et al., (1973), after analyzing data collected during the Joint North Sea Wave Observation Project JONSWAP, found that the wave spectrum is never fully developed. It continues to develop through non-linear, wave-wave interactions even for very long times and distances. The JONSWAP spectrum is similar to the Pierson-Moskowitz spectrum except that waves continues to grow with distance (or time), and the peak in the spectrum is more pronounced. The latter turns out to be particularly important because it leads to enhanced non-linear interactions and a spectrum that changes in time according to the theory of Hasselmann (1966).

A number of buoys are known in the art which measure wave height and other data using accelerometers or other instruments. Hue, U.S. Pat. No. 4,515,013, issued May 7, 1985, and incorporated herein by reference, discloses a buoy with accelerometers and magnetometers, for measuring the vertical acceleration, but fails to teach or suggest an algorithm for determining wave direction or wave slope from wave spectra. Luscombe, U.S. Pat. No. 4,986,121, issued Jan. 21, 1991, and incorporated herein by reference, discloses an apparatus for measuring the vertical movement of a floating platform. This reference appears to be along the lines of Hue above, in that it only measures vertical motion. Such devices are useful in determining wave heights but do not appear to detect wave direction or other spectral data.

Harigae, U.S. Pat. No. 6,847,326, issued Jan. 25, 2005, and incorporated herein by reference, discloses a floating device for measuring wave height and tidal current direction and speed using GPS technology. This apparently free-floating buoy uses GPS data to determine tidal current direction and speed. The reference does not appear to teach measuring wave direction, slope, or other spectra. Von Wald, Jr., U.S. Pat. No. 3,310,047, issued Jan. 31, 1967, and incorporated herein by reference, discloses a wave gauge array for obtaining ocean wave spectra. This device appears to only measure wave height.

Mayberry, Published Japanese Patent Application 6014991 published Aug. 7, 1985, and incorporated herein by reference, discloses an apparatus for detecting of wave motion azimuth. From the translated Abstract, it does not appear that this reference measures more than wave height. Yamaguchi, Published Japanese Patent Application 2005083998, published Mar. 31, 2005, and incorporated herein by reference, discloses a GPS Ocean Wave Measuring Device. This device appears to measure only the period of the wave.

A number of non-patent literature documents disclose wave-measuring buoys. Pitch-Roll Buoy Wave Directional Spectra Analysis, Accession Number: ADP000383, by LeBlanc, L. R.; Middleton, F. H. (November 1982, Rhode Island University, Kingston) discloses a single small buoy, either free-floating or tethered to an anchor, designed not to follow the slope of the water surface, but instead to pitch and roll according to the orbital particle-velocity gradient. The dynamics of this buoy system are such that the data obtained on heave, pitch, roll, and compass bearing can be transformed into complete directional wave spectra. The buoy used to